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DEFENCE RESEARCH ESTABLISHMENT OTTAWA

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ABSTRACT

Test samples of textile materials of 2.5, 7.6, 15.2 or 30.5 cm diameter were exposed to thermal radiation sources at ~~Sandia~~ Central Receiver Test Facility and the ~~DNA~~ Thermal Radiation Source at Kirtland Airforce Base, ~~New Mexico~~. The materials were exposed to fluences of 5, 10, 15 and 30 cal cm^{-2} in 1 or 3 seconds. The thermal pulse was square or approximately that of 1 KT weapon. Generally, damage to materials increased with an increase in the test sample diameter. High speed photography showed the large diameter samples (30.5 cm) ignited prior to 2.5 cm diameter samples. It was evident that testing with small samples of material would over-estimate the protection afforded. Comparison of test results of materials exposed to simulated and non-simulated nuclear weapons support the conclusion that protection is over-estimated by assessment of damage on exposed small test samples.

RÉSUMÉ

Des échantillons de matéraux textiles de 2.5, 7.6, 15.2 ou 30.5 cm de diamètre furent exposés à des sources de radiation thermale au Sandia Central Receiver Test Facility et au DNA Thermal Radiation Source du Kirkland Airforce Base au Nouveau Mexique. Les matériaux furent exposés à des degrés de chaleur de 5, 10, 15 et 30 cal cm^{-2} en 1 ou 3 secondes. Les pulsations thermales étaient carrées ou approximativement celles d'une arme de 1 KT. Généralement, les dommages aux matériaux augmentaient avec l'augmentation du diamètre des échantillons. Une photographie à haute vitesse montra les échantillons de 2.5 cm de diamètre. Il était évident que les tests avec des petits échantillons de matéraux surestimerait la protection offerte. Des comparaisons entre les résultats de tests de matériaux exposés à des armes nucléaires simulées et non-simulées supportent la conclusion que la protection est surestimée par l'évaluation des dommages sur de petits échantillons exposés.

EXECUTIVE SUMMARY

Simulation of a nuclear thermal pulse involves modelling the spectrum and the flux of nuclear weapons and requires a source of adequate size for testing small and large samples. The difficulty of this problem has led to the development of thermal sources with quite different spectra and pulse shapes and systems having different limitations on the size of the sample which can be exposed. Consequently, uncertainties have arisen as to the interpretation of results obtained with different sources and/or with different sample sizes.

In order to evaluate this effect, test samples of textile materials of 2.5, 7.6, 15.2 or 30.5 cm diameter were exposed to thermal radiation sources at Sandia Central Receiver Test Facility and the DNA Thermal Radiation Source at Kirtland Airforce Base, New Mexico. The materials were exposed to fluences of 5, 10, 15 and 30 cal cm^{-2} in 1 or 3 seconds. The thermal pulse was square or approximately that of 1 KT weapon.

Thermal flux and fluences were measured at each source and temperature-time profiles were measured at the surface using fast-response thermocouples. As well, tissue-equivalent plastic (TEP) was used to determine the extent to which materials would protect the skin against burns. The time-to-first emission of smoke was taken as a criterion for damage.

It was found that the damage to exposed samples 10.2 x 7.6 cm was comparable to that obtained in the fully clothed manikins. Generally, damage to materials increased with an increase in the test sample diameter. High speed photography showed the large diameter samples (30.5 cm) ignited prior to 2.5 cm diameter samples. It was evident that testing with small samples of material would over-estimate the protection afforded. Comparison of test results of materials exposed to simulated and non-simulated nuclear weapons support the conclusion that protection is over-estimated by assessment of damage on exposed small test samples.

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1.0 INTRODUCTION

Simulation of a nuclear thermal pulse involves modeling the spectrum and the flux of nuclear weapons and requires a source of adequate size for testing small and large samples. The difficulty of this problem has led to the development of thermal sources with quite different spectra and pulse shapes and systems having different limitations on the size of the sample which can be exposed. Consequently, uncertainties have arisen as to the interpretation of results obtained with different sources and/or with different sample sizes.

In the course of an on-going research program on the development of protective equipment and clothing, Defence Research Establishment Ottawa (DREO) has conducted several investigations in which materials were exposed to large thermal radiation sources either alone or in combination with blast effects (1-4). The program of testing materials and clothing for thermo-resistance provided an opportunity to explore some of the uncertainties relating to source characteristics and sample sizes.

2.0 EXPERIMENTAL

2.1 THERMAL SOURCES

Two thermal sources were used during the investigation. The Sandia Central Receiver Test Facility (CRTF) and DNA Thermal Radiation Source (TRS) at Kirtland Airforce Base. The Sandia CRTF is extensively described in the Sandia Report (5). The (CRTF) has a 73.15 m test bay and can deliver up to 5 megawatts through a 1 m shuttered aperture onto a target area of 1 m^2, giving a flux of up to 120 cal cm^{-2} s^{-1}. The shutter has timed vertical panels which are drawn apart symmetrically at high speed by an electronically timed pneumatic drive. The test samples were mounted in panels which were attached to single racks measuring 76.2 cm x 71.1 cm. The spread of the flux values on the samples was uniform, within 8.5%. The source was used in two different configurations: in one experiment a square pulse was used and in a separate experiment the pulse shape was similar to that of a nuclear weapon (see Figures 1, 2, 3).

2.2 DNA SOURCE

The materials were exposed to the Defense Nuclear Agency thermal radiation source (TRS) at Kirtland Airforce Base, New Mexico, U.S.A. The TRS is intended to simulate radiant heat emitted by the fireball from airburst tactical nuclear weapons.

The source is unique in that it can accommodate a target 9.14 m long and 3.65 m high and provide a flux of up to 70 cal $cm^{-2} s^{-1}$. The pulse shape is square, Figure 4, with a rise time (i.e. time to peak) of less than 0.3 s and with a total pulse duration of up to 5 s or more. Emission spectrum of the TRS corresponds to a black body temperature of 2,800°K and is thus composed of longer peak wave-length photons than 6,000°K of nuclear weapon fireball.

The TRS operates in a fenced outdoor test bed and consists of a linear array of four upwardly-directed specially designed nozzles, each of which produces a flame two meters in diameter and six meters in height. The heat is produced by the chemical reaction between liquid oxygen (LOX) and aluminum powder flowing through the nozzles at a rate greater than 5 liters per second and 5 kg per second, respectively. The nozzle spacing can be varied from 0.91 m to 3.05 m.

2.3 THERMAL MEASUREMENTS

2.3.1 Calorimeters

The thermal flux and fluences were measured at the DNA source using 2.5 cm diameter air cooled calorimeters (Medtherm Corp. Cat. No. 64XX-15) which were calibrated at BRL Aberdeen Proving Ground. These calorimeters were used in a series of preliminary burns to map the pattern of the flux from the source so as to establish the expected positions of the fluences for the exposure of the targets for 1 s.

2.4 MEASUREMENT OF THERMAL FLUX AT CRTF

In the case of the CRTF Facility six small water-cooled flux gauges 0.63 cm in diameter were located around the edge of the target rack. The tranducers were calibrated employing the same source radiation spectrum as that received by the targets (5).

2.5 TEMPERATURE

Temperature-time profiles were measured in all investigations employing surface fast-response thermocouples, (i.e. zig-zag "K-Type 2.54 cm thermocouples imbedded in Kaptc.. manufactured by Hy Cal Engineering). The thermocouples have a rise time of 68% in 20 milliseconds.

2.6 TISSUE EQUIVALENT PLASTIC (TEP)

The TEP was used to determine the extent to which materials would protect the skin against burns. The grading scale used to interpret observed change to TEP in terms of fluence ranges corresponding to differing degrees of burns to the skin is given in Table I. The TEP is described in references (6, 7) and was used in all trials.

TABLE I

TEP Grade and Interpretation (Number)

1 = Texture unchanged	=	no burn Fluence < 2.25 cal cm^{-2}
2 = Slight smoothing	=	1st degree burn Fluence 2.25 to 4 cal cm^{-2}
3 = Smooth and shiny	=	Second degree burns Fluence 4 to 6 cal cm^{-2}
4 = Holed	=	Third degree burns * Greater than 6 cal cm^{-2}

2.7 PHOTOGRAPHY

Colour photographs of targets were made pre and post exposures using a Pentax 35 mm camera.

A Lo-Cam camera operating at 400 frames per second was used to record events during all trials.

2.8 MATERIALS AND SAMPLE SIZES

The materials exposed are listed in Table II. The samples were placed between 2 mm thick anodized aluminum plates 2.54 cm or 38.1 cm by 71.1 cm and exposed through circular holes. The area of the sample exposed was determined by the diameter of circular holes cut in the plates which were 2.5 cm, 7.6 cm, 15.2 cm and 30.5 cm apertures.

TABLE II

Materials Exposed

1. Canadian NBC clothing (NBC)
2. Butyl rubber on Fiberglass Fabric (BYF)
3. Bromobutyl-on-glass (B11R-G)
4. Neoprene-on-glass (CR)
5. Bromobutyl-on-nylon (B11R-N)
6. Nitrile-on-glass (NBG)
7. Teflon-on-aluminum (T/A)
8. Epichlorophydrine-on-glass (ECO)
9. Kapton (KAP)
10. Teflon-on-vinyl (T/V)
11. Ultem (ULT)
12. ECTFE/Vinyl (E/N)
13. ECTFE/Aluminum (EA)

To investigate the protection afforded by an outer layer separated from an inner layer by an air gap, a special sample holder was constructed.

2.9 PULSE SHAPE

The pulse shape of the thermal radiation delivered to targets at the TRS site was square-waved and is shown in Figure 4. The pulse shapes employed at CRTF are shown in Figures 1 and 2. The non-square pulse did not quite simulate a typical pulse shape of the radiation from 1 KT weapons, Figure 3, as the response of the shutter was slightly slow (8).

Not all materials listed in Table II were exposed to both sources, and the 30.5 cm sample size was exposed for only a few materials.

3.0 RESULTS

The effect of test sample sizes was assessed from the exposure to a square pulse on the TRS and the CRTF source. Also the samples were exposed at the CRTF source to a pulse shape which is similar to a nuclear weapon (see Figure 1). The effect of smoke on the pulse shape is shown in Figure 5. As it was evident that there was a shielding effect from the smoke, it should be noted that the program which was used to calculate fluences takes into account the large drop in flux.

Inspection of the measured values of fluence from the CRTF exposures showed that in several instances, the fluence differed by large percentages between exposures, despite being under the same

conditions and location in the same rack of panels. This variation creates problems in the interpretation of damage effects and thermoresistance. A linear interpolation procedure was used to estimate the probable value of the fluences actually received by each sample and these test estimates are used in the effect tables. Although duplicate samples of each material were exposed only the average damage estimate is reported. A summary of data reported previously (4) is given in Table III for 2.5 cm to 30.5 cm diameter samples exposed to nominal 5 and 15 cal cm^{-2}. It is evident from Table III that, for the majority of the materials the 15.2 cm and 30.5 cm diameter samples were more severely damaged than the 2.5 cm and 7.6 cm diameter samples. Some of the 7.6 cm sample data has been excluded for simplicity.

Another method for assessing the effect of sample size and damage is to determine the time for initiation of smoke or ignition. The analysis of the Lo-Cam camera film produced the data given in Table IV. The time at which shutter first opened to begin exposure to the flux at the center panel on the rack was taken as the zero-time. The time to fully open the shutter was approximately 160 ms, it began closing after about 2600 ms and was fully closed approximately after 2800 ms. The outerpanel received a flux starting about 70 ms earlier than did the midline of samples loaded on the left and right panels on the rack.

The majority of samples emitted smoke at some point during exposure but flaming was rarely seen even for the 30.5 cm samples at high fluences.

The time to the first emission of smoke was taken as a criterion of damage. Table IV gives the estimated times of emission of first smoke relative to the time of the first flux received at the midline of the samples. Shown in brackets beside each time is the accumulated fluence on the samples up to that time as estimated from the flux gauge data and motion of the shutter. The data for 5 cal cm^{-2} for 7.6 cm diameter samples are not available due to the illegibility of the photo film. In other cases the film was difficult to read, thus judging the onset of smoke was subject to considerable error. Nevertheless in a number of cases in which there was comparable data, a number of larger samples produced smoke before it appeared in the 2.5 cm diameter samples at a lower fluence. For the NBC and BYF materials, although not always consistent, the 30.5 diameter samples showed smoke prior to the other sample sizes. Also the time for remission of smoke decreased with the increase in fluence. The other samples showed similar trends but there were exceptions.

The former experiment was conducted on the CRTF, which has a pulse shape similar to a nuclear weapon, although the exposure time was longer. A second experiment was conducted at the CRTF employing a square pulse and an exposure time of 1.1 s (Figure 2).

TABLE III

Effect of Fluence and Sample Size on Materials Exposed to Thermal Peak Pulse from the CRTF Source

Materials	5 cal cm^{-2}			15 cal cm^{-2}		
	2.5 cm	15.2 cm	30.5 cm	2.5 cm	15.2 cm	30.5 cm
NBC Clothing	N(3.8)* 1**	DC(4.9) 1	DC(4.5) 1	H(14.0) 1	H(11-11.1) 1	D(12.0) 4
BYF	B(3.8) 1	D(4.9) 2	H(3.0) 4	B(13.9) 1	H(10.8) 4	D(12.4) 4
B11R/G	DC(3.9) 1	S/N(4.9) 2	-	B(13.8) 4	S(9.5) 4	-
CR	DC(4.2) 1	S(5.0) 2	-	H(14.9) 4	B(14.0) 4	-
B11R/N	S(4.8) DC(3.9)	D(5.1) 4	-	H(13.3) 4	D(12.8) 4	-
NBR/G	N(4.7) 1	DC(5.8) 4	-	B(11.5) 4	B(10.5) 4	-
ECO	DC(4.8) 3	DC(6.6) 4	-	B(12.1) 4	B(10.5) 4	-
KAP	N(4.7) 2	N(5.1)	-	H(11.7) 4	-	-
ULT	H(4.7) 4	-	-	H(11.0) 4	-	-
EA	-	N(5.5)	-	-	N(10.4)	-
TU	-	-	-	-	-	-

* Actual Fluence
N = Normal (no damage)
B = Burnt
D = Destroyed

** TEP Grade - Table 1
DC = Discoloured
H = Holed
S = Scorched

TABLE IV

Time and Fluence at Earliest Emission of Smoke by Materials Exposed to Peak Pulse from the CRTF Sources

Sample Size	Nominal Fluence	Time in Milliseconds*						
		NBC	BYF	B11R/G	CR	B11R/N	NBR/G	ECO
2.5 cm	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	10	367(4.0)	*200(2.7)	330(3.8)	430(4.3)	N/A	N/A	N/A
	15	225(4.0)	115(2.6)	N/A	345(4.5)	195(3.5)	195(3.5)	265(3.5)
	20	310(6.4)	122(2.6)	192(2.6)	202(2.8)	57(1.6)	57(1.6)	225(3.2)
7.6 cm	5	-	-	-	-	-	-	-
	10	381(4.4)	182(2.4)	115(2.4)	227(2.2)	210(2.7)	175(2.4)	155(2.3)
	15	155(1.9)	155(1.9)	225(2.8)	215(2.7)	197(3.1)	197(3.1)	207(3.0)
	20	335(6.1)	125(3.4)	152(3.7)	380(5.9)	150(3.4)	150(3.4)	142(2.5)
15.2 cm	5	N/A	N/A	N/A	N/A	N/A	185(1.8)	365(5.7)
	10	442(4.3)	165(2.2)	442(3.7)	177(2.7)	295(3.7)	177(2.4)	510(5.7)
	15	255(3.3)	222(1.3)	472(4.8)	-	-	-	-
	20	322(4.6)	- (1.3)	280(4.9)	140(2.4)	115(2.3)	102(2.3)	187(3.7
30.5 cm	5	325(4.2)	262(1.5)	N/A	N/A	N/A	N/A	N/A
	10	372(4.2)	112(1.5)	"	"	"	"	"
	15	142(2.1)	107(1.3)	"	"	"	"	"

* Time in milliseconds from first flux on sample midline until earliest emission of smoke. (Fluence at that time in cal cm^{-2}).

N/A = Not available.

The measurement of thermal flux temperature and photography and sample sizes were the same as previously described (2). The effects of fluence and sample size on the material, NBC and BYF and skin simulant TEP are given in Table V along with data obtained when the nuclear pulse shape was used. The letter codes for the damage levels are shown for each material in each sample size at each fluence. Immediately under each letter code is a number indicating the damage to the tissue equivalent plastic (TEP) behind the corresponding samples. The TEP grade scale and interpretation is shown below the table along with the list of fabrics exposed. It is evident from Table V that for the fabrics tested, the damage increased with an increase in the fluence and with an increase in sample size.

A relation between sample size and protection afforded can be assessed by placing the TEP behind each sample. The grading assigned to fabrics and TEP is given in Table III. Caution must be used to interpret the data because in some cases the TEP was separated from direct contact with the rear surface of the materials by an air gap of as much as 2 to 4 mm. If the TEP was in contact with material exposed to more than 5 cal cm^{-2}, it melted. From Table 1V for materials exposed to 5 and 15 cal. cm^{-2} in almost all cases less protection was afforded to the surface of the larger samples.

In comparison, the damage of samples exposed at CRTF source to the two pulse shapes, a square wave and a weapon-shape pulse peaks, consideration must be given to the difference in exposure time. The exposure time when the thermal radiation was delivered in a square pulse was 1 s. For the peak pulse shape, over 98% of the fluence was delivered in 2.1 s, with 50% of fluence delivered in 0.9 s and the last amount in 1.2 s. However, for materials NBC and BYF exposed to two pulses on the same source and fluence, there was little difference (Table V). It is evident that pulse shape had no effect on the damage and any small difference in flux did not produce any significant effects.

Data from different sources and pulse shapes from a number of investigations were compiled and analysed. Comparison of data from the two sources and using square pulse exposure conditions indicated that for NBC materials, exposure to the TRS caused less visual damage, but this may have been due to receiving a lower fluence. There was no difference for BYF materials. Also there was no significant difference in the burn index behind the materials as measured by the TEP.

TABLE V

Comparison of Damage to Fabrics and TEP Skin Simulant Exposed to Square and Peaked Pulse Shapes from the CRTF Source

	5 cal cm^{-2}				10 cal cm^{-2}				15 cal cm^{-2}				20 cal cm^{-2}			
	2.5cm	7.5cm	15.2cm	30.5cm	2.5cm	7.5cm	15.2cm	30.5cm	2.5cm	7.6cm	15.2cm	30.5cm	2.5cm	7.6cm	15.2cm	30.5cm
NBC - Peak Pulse																
Fluence	2.8	5.4	4.8	4.0	8.2	8.5	9.7	8.6	14.0	9.0	9.8	12.0	21.4	20.8	18.6	-
Cloth Damage	N	DC	DC	DC	B	B/H	B/H	D	H	B	H	D	H	H	D	-
TEP Grade	1	1	1	1	1	1	1	4	1	1	1	4	4	4	4	-
NBC - Square Pulse																
Fluence	3.8	-	-	-	9.0	-	-	-	15.2	-	-	-	-	-	-	-
Cloth Damage	B	DC	DC	D	B	H	H	-	B	D	D	-	-	-	-	-
TEP Grade	1	1	1	4	1	1	1	-	1	3	3	-	-	-	-	-
BYF - Peak Pulse																
Fluence	3.8	5.2	4.8	3	6.3	7.2	10.4	7.5	13.9	8.1	9.7	13.0	20.8	19.3	17.8	-
Cloth Damage	B	DC	D	H	B	B/H	H/D	D	B	B	B/H	H	B	B/H	H	-
TEP Grade	1	1	2	3	1	1	4	4	1	1	4	4	-	4	4	-
BYF - Square Pulse																
Fluence	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cloth Damage	B	H	H	H	B	H	D	D	B	H	-	-	-	-	-	-
TEP Grade	1	1	2	3	2	2	3	4	3	3	-	-	-	-	-	-

NOTES: Cloth Damage: N = No Damage; DC = Discoloured; B = Burned; H = Holed; D = Destroyed
TEP Grades: 1 = No Burn; 2 = 1st Degree Burn; 3 = 2nd Degree Burn; 4 = 3rd Degree Burn

4.0 DISCUSSION

Based on the limited data, the indications are that differences in black body radiation between sources has no effect on the resulting damage. Schallon, Baba, Share (9) employing a solid target material, in which there was no smoke interference, also found little difference in temperature rise or damage on the material exposed to a source with different black body spectrum. It is also evident that for any source or pulse shape, the larger (30.5 cm diameter) exposed samples showed more damage than the 2.5 cm diameter samples.

This could be due either to protection by smoke or diffusion of oxygen. Also one can speculate that the surface of the larger samples is not as planar as the small samples and that the non-planar surface may cause micro hot spots and smoke prior to samples which have more planar surfaces. Observation damage to clothed manikin exposed to thermal sources revealed that only part of the trouser legs which are not planar are burnt.

The effect of sample size compared to whole assemblies was studied at earlier nuclear trials in the 1950s.

The damage to exposed samples 10.2 cm x 7.6 cm (77.4 cm^2) was comparable to that obtained with fully clothed manikins. In the present investigations the 2.5 cm and 7.6 cm diameter samples showed less damage than the larger 15.2 cm and 30.5 cm diameter samples (182.3 and 729.3 cm^2) and clothed manikins. However, even larger samples do not provide totally conclusive information because exposed full assemblies do not show uniform damage over the whole surface and it is important to know the damage caused to the critical areas, such as the knees, elbows, hands, feet and thighs. Therefore, it is not prudent to rely solely on the exposure of large samples to assess the protection afforded by complete clothing assemblies. The rise time of the thermal pulse from a weapon is faster than from simulators and this can make considerable difference to the resulting damage. A number of cloths developed in the fifties were assessed employing a solar furnace and 1 cm^2 samples at DREO (10). The results indicated that fabrics could be protected by Nimbus cloth up to approximately 30 cal cm^{-2} delivered in 1 second. Sitting manikins dressed in NBC protective suits protected by Nimbus cloth were exposed to approximately 30 cal cm^{-2} fluence in a nuclear weapon trial (20 KT) and were completely destroyed, while those exposed to 17 cal cm^{-2} survived. The Nimbus cloth provided protection to clothed manikins when exposed to a DNA TRS source at approximately 17 cal cm^{-2} as well as to nuclear weapons, but the system failed in nuclear trials. It is evident that even data obtained from exposure of whole clothing assemblies to a thermal pulse simulated nuclear source should be assessed with caution as protection factors may be over-estimated by at least a factor of two.

5.0 REFERENCES

1. Grant, G. A. Thermoresistance of Prototype NBC Mask Canisters and Clothing Materials: Part I: TRS Studies on Canisters and Materials. Contract Report, Contract No. 14SV.W7714-7-5258. DSS Serial No. W7714-7-5258/01SV. March 1988.

2. Grant, G. A. Thermoresistance of Prototype NBC Mask Canisters and Clothing Materials. Part II: Thermoresistance of Materials tested on Sandia's Solar Central Receiver Test Facility (CRTF). Contract Report No. 13SV/W7714-7-5301. May 1988.

3. Part III, G. A. Grant - Thermoresistance of Prototype NBC Mask Canisters and Clothing Materials. Thermoresistance of Materials Tested on Sandia Solar Center Receiver Facility. Contract No. W7714-5606 Feb. 1989.

4. Grant, G. A. and Constantine, L. Thermoresistance of Prototype NBC Mask Canisters and Clothing Materials; Part lV TRS Studies on Various Fabrics Caped/Clothed Manikins and Clothing Materials. DDS Contract No. 35Y.W7714-8-5606, March 1989.

5. Sandia Central Receiving Test Facility - Sandia Report No. SAND 86 - 1492 January 1987.

6. Mehta, P. and Willerton, K., Evaluation of Materials for Protection against Molten Metal. Textile and Industry, pg 344, October 1977.

7. Stores and Clothing Research and Development Establishment Ministry of Defence, Flagstaff Road, Colchester, Essex England, as referenced in Textile and Industry, pg 344, October 1977.

8. The Effect of Nuclear Weapons, Third Edition, Samuel Glasstone and Phillip J. Dolan 1977.

9. Schallon, B. J., Baba, A. J. and Share S., Page 657 Proceeding Eleventh International Symposium on Military Applications of Blast Simulation, 10-15 September 1989

10. Cavanagh, P., Drew, G.G. and Wilson, L.G., Tests of Canadian Nimbus Cloth, DREO Technical Note 66-18, July 1966.

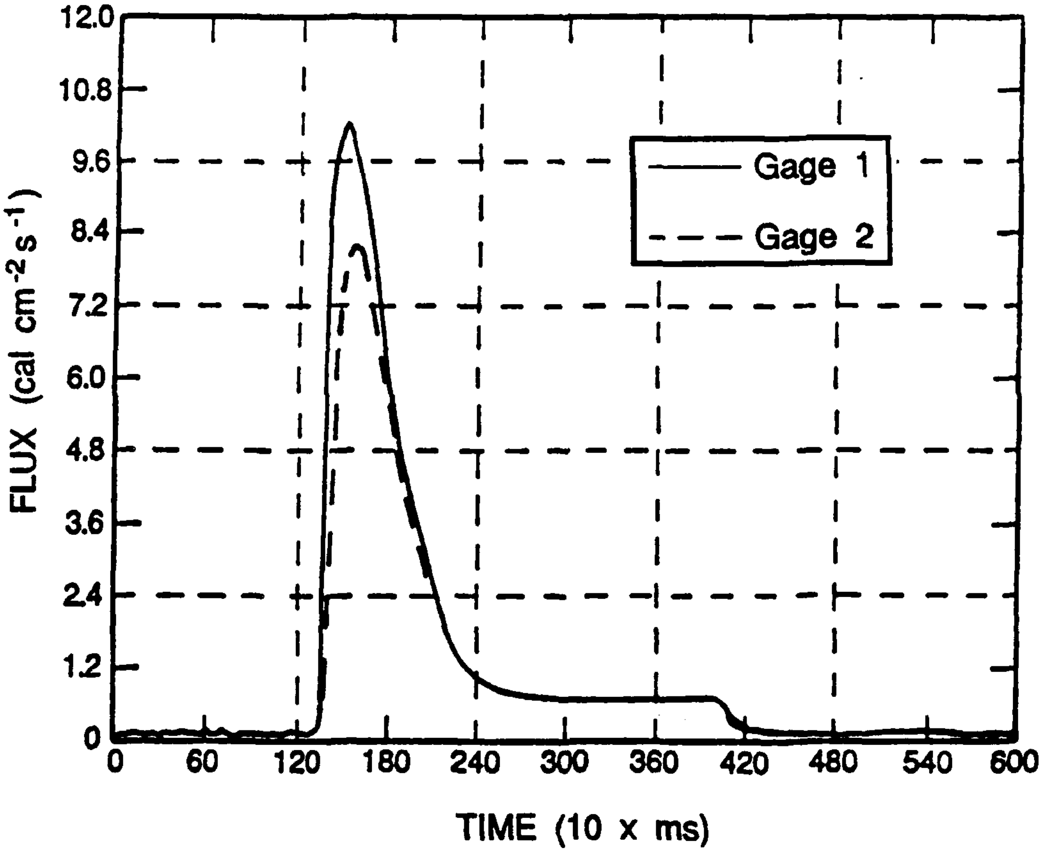

Figure 1. CRTF flux-time profile from flux gages.

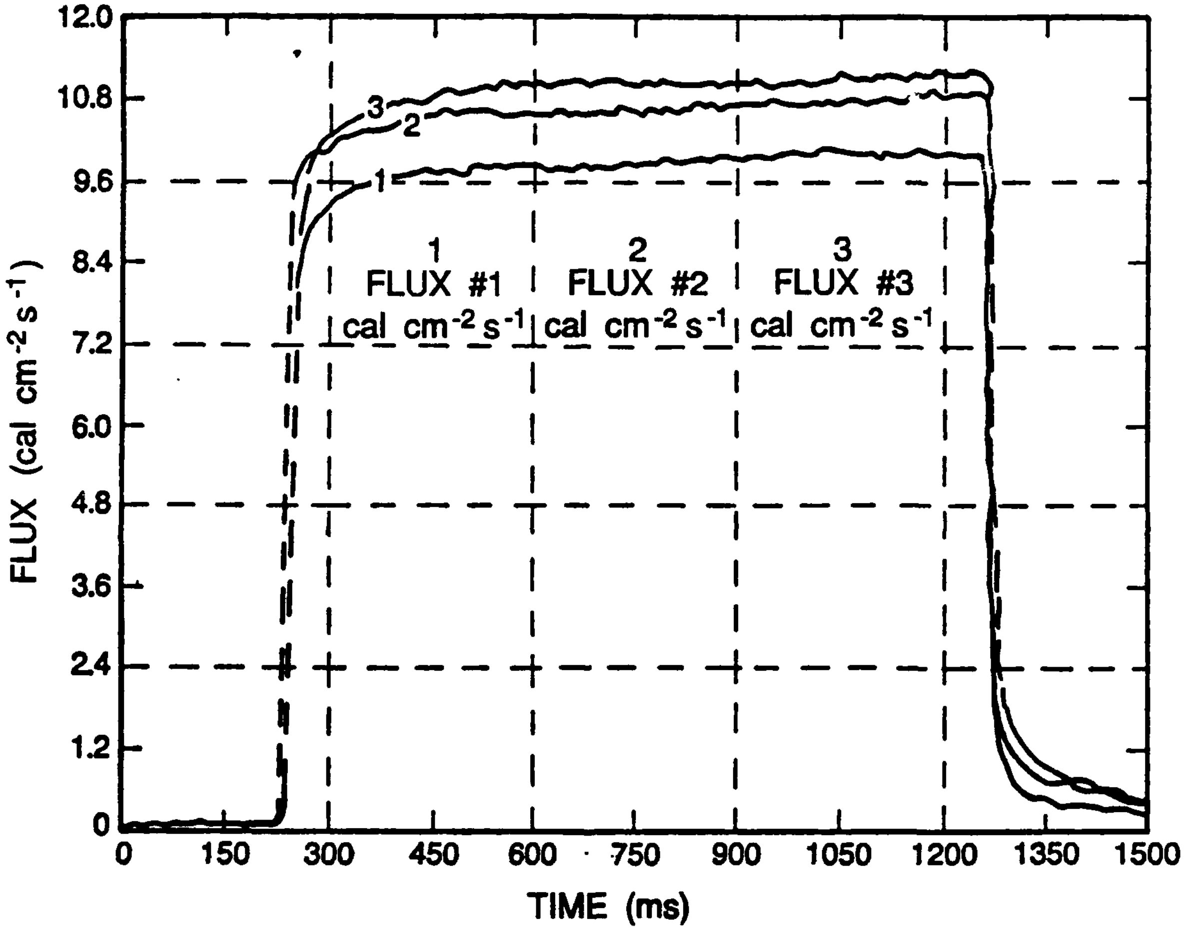

Figure 2. Sample flux-time profile for 10 cal cm^{-2} fluence.

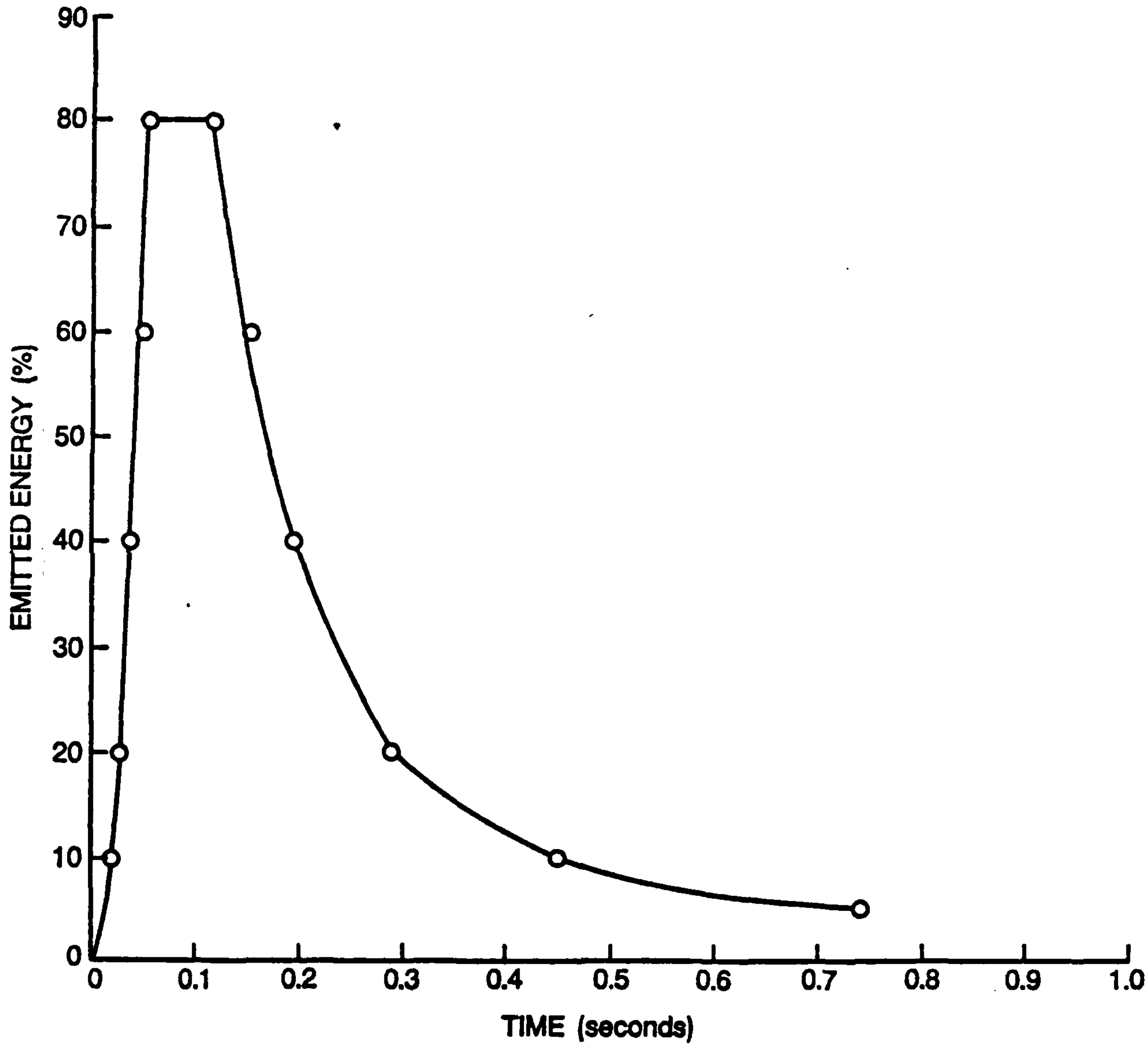

Figure 3. Desired shape of thermal pulse for materials testing.

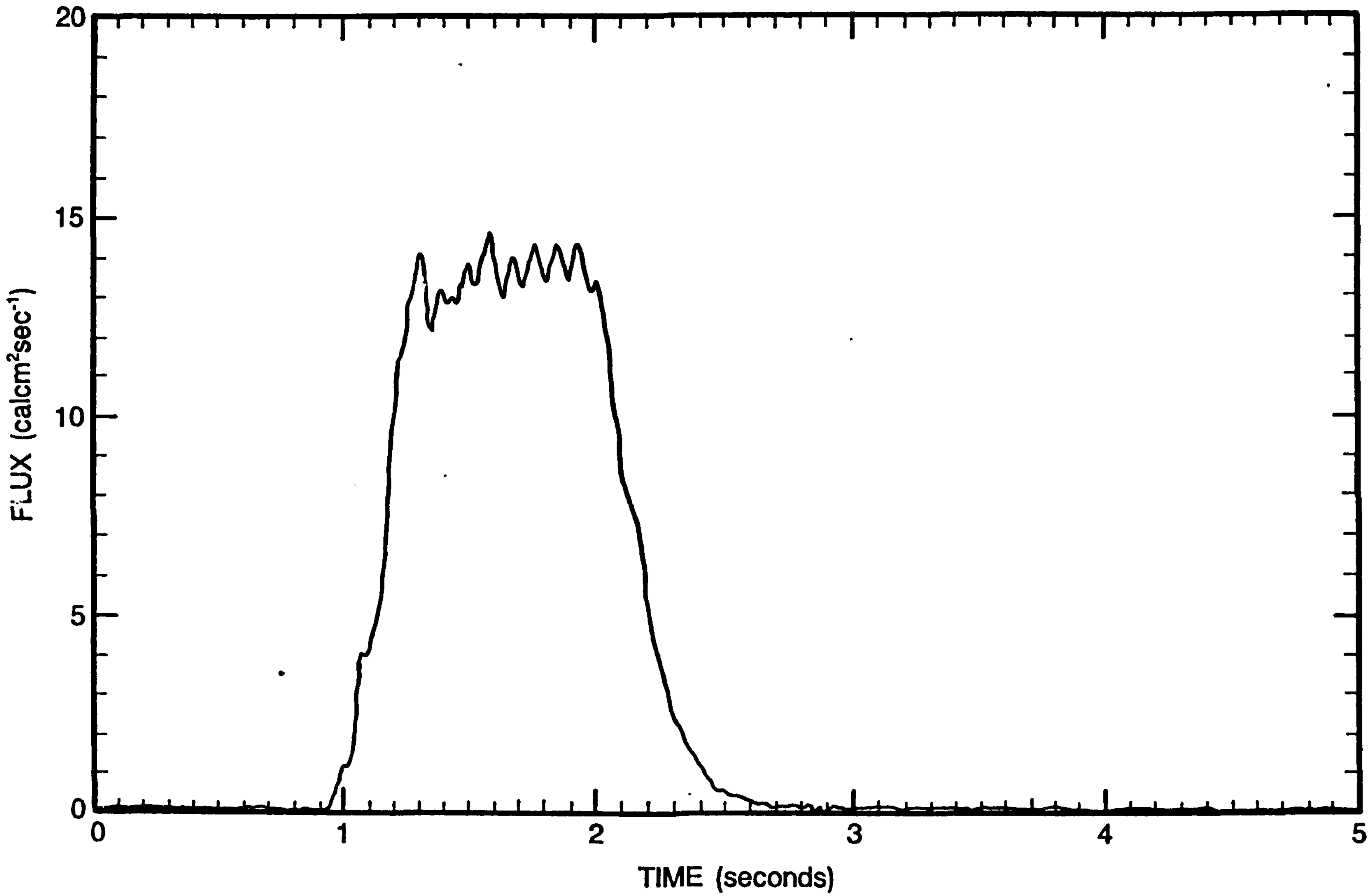

Figure 4. Shape of pulse from DNA source.

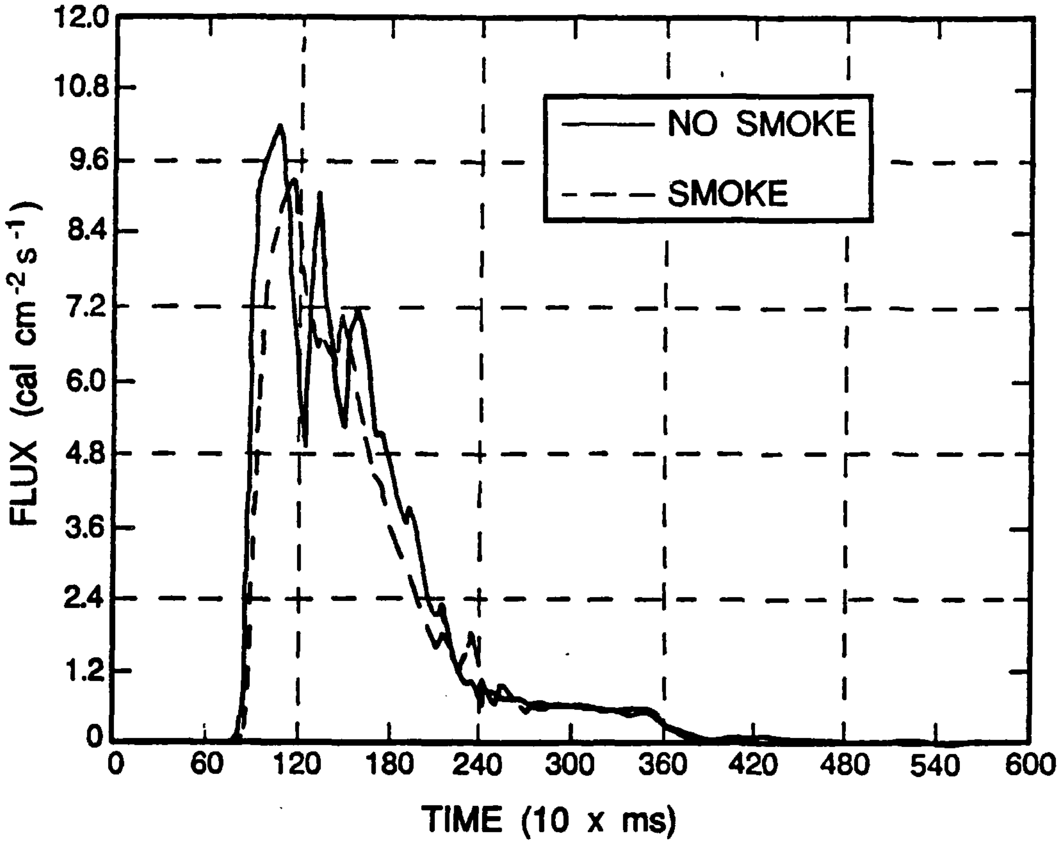

Figure 5. A flux-time profile showing smoke effects.

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Test samples of textile materials of 2.5, 7.6, 15.2 or 30.5 cm diameter were exposed to thermal radiation sources at Sandia Central Receiver Test Facility and the DNA Thermal Radiation Source at Kirtland Airforce Base, New Mexico. The materials were exposed to fluences of 5, 10, 15 and 30 cal cm^{-2} in 1 or 3 seconds. The thermal pulse was square or approximately that of 1 KT weapon. Generally, damage to materials increased with an increase in the test sample diameter. High speed photography showed the large diameter samples (30.5 cm) ignited prior to 2.5 cm diameter samples. It was evident that testing with small samples of material would over-estimate the protection afforded. Comparison of test results of materials exposed to simulated and non-simulated nuclear weapons support the conclusion that protection is over-estimated by assessment of damage on exposed small test samples.

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